

**Summary of Published Measurements  
of Asbestos Levels in Ambient Air**

Prepared for USEPA Region 8  
Denver, CO

by

SRC, Inc.  
Denver, CO

05//20/2013

## **Summary of Published Measurements of Asbestos Levels in Ambient Air**

### **1.0 Introduction**

Libby, Montana, is a community that has been impacted by past and potentially on-going releases of asbestos into air from waste materials associated with historic mining activities at a nearby vermiculite mine. However, it is important to understand that asbestos is a naturally-occurring material and has also been widely used in commercial products in the past, and particles of asbestos are often detectable in air at locations that are not associated with any specific sources. The purpose of this technical memorandum is to summarize data from published reports on the levels of asbestos that have been reported in air at a number of other locations across the country. These data provide a perspective on “background” levels of asbestos in air, and may help with risk management decision-making at the site.

### **2.0 Strategy for Locating Information on Airborne Concentrations of Asbestos**

Primary and secondary literature sources were screened for information on ambient concentrations of airborne asbestos in outdoor air and in buildings in the United States. The strategy for locating relevant documents included:

- Bibliographic searches were conducted using Medline and Toxline
- Review documents (e.g., WHO 1988, HEI-RI 1991, ATSDR 2001) were screened for data and for additional relevant references to primary reports
- Bibliographies of relevant reports were reviewed for other relevant citations
- A search was conducted on the internet using Google.

Types of data intentionally excluded from this summary include:

- Data collected in occupational settings
- Data collected during asbestos remediation or removal activities at asbestos-contaminated buildings or industrial sites
- Data collected during building renovation or maintenance activities, because such activities often result in exposures much higher than for typical building occupants (e.g., Keyes and Millette 1991, Kinney et al. 1994)
- Data collected in regions with high levels of naturally-occurring asbestos (e.g., sites reviewed by Harper 2008)
- Data associated with building collapse or demolition (e.g., levels associated with destruction of the World Trade Center)

- Data from locations outside the United States

### 3.0 Results

#### 3.1 Overview

Asbestos in air is measured by using a pump to draw air through a filter and examining the filter under a microscope to estimate the number of asbestos fibers on the filter.

There are a wide range of options for how a sample is collected and analyzed and how the results are reported. Chief among these variables are the following:

- Sample Collection. Samples are usually collected by placing the filter and pump in a fixed location. In other cases, the pump and filter may be worn by a person engaged in normal behavior. Such samples are referred to as personal samples. In some cases, personal samples may tend to yield higher concentrations values than stationary samples, presumably because the person's activities tend to disturb asbestos in dust.
- Microscopic technique. Historically, the primary microscopic technique used for measuring asbestos in air was phase contrast microscopy (PCM). This technique has the disadvantage of not being able to reliably distinguish asbestos fibers from non-asbestos fibers, and it cannot reliably detect fibers thinner than about 0.25  $\mu\text{m}$ . More recently, transmission electron microscope (TEM) has become the preferred technique. While more costly, TEM can distinguish asbestos from non-asbestos, distinguish between different types of asbestos, and can resolve even very thin fibers.
- Counting rules. Counting rules specify what structures on a filter are to be recorded and included in the calculation of the concentration value for a sample. In PCM analyses, a fiber is defined as a structure with roughly parallel sides, a length of at least 5  $\mu\text{m}$ , and an aspect ratio (length / width) of at least 3:1. Most TEM counting rules are similar, except that fibers as short as 0.5  $\mu\text{m}$  are also usually recorded.
- Stopping rules. In all microscopic analysis methods, only a small portion of the filter can be examined at a time. Stopping rules specify how much of the filter must be examined before stopping. The amount of area examined is an important determinant of "detection limit". That is, the more area examined, the greater the ability to detect fibers on the filter.
- Reporting units. In the early days of asbestos analysis, concentration was often reported on a mass per unit volume basis (e.g.,  $\text{ng}/\text{m}^3$ ). However, reporting concentrations as fibers or structures per unit volume (e.g.,  $\text{f}/\text{cc}$ ,  $\text{s}/\text{cc}$ ) soon

because standard. As noted above, this may be either for total fibers longer than 0.5  $\mu\text{m}$ , or may be restricted only to fibers longer than 5  $\mu\text{m}$ .

- Sample preparation. When a filter is examined, excess particulate matter on the surface can interfere with the ability to see and count fibers. In this case, the material on the filter is suspended in water, and a portion of the water suspension is applied to a new filter (thereby decreasing the amount of material on the new filter). In general, this process (referred to as indirect preparation) often tends to cause an apparent increase in fiber count, so direct preparations (without the water suspension step) are generally considered to be most reliable. Most samples of ambient air contain sufficiently little particulate matter that direct analysis is generally possible.

Because of these variations in sampling and analysis techniques, caution must be taken when comparing results between different studies that used different sampling, preparation, or analysis methods. For the purposes of this summary, whenever possible, emphasis is placed on TEM data reported in units of fibers longer than 5  $\mu\text{m}$  per cubic centimeter of air (f/cc). This is because a) TEM analysis is most reliable in distinguishing asbestos from non-asbestos, and b) current techniques for evaluating the potential risks to humans from inhalation exposure to asbestos are based on exposures described in terms of f/cc longer than 5  $\mu\text{m}$ . PCM data, when presented, may tend to be higher than TEM data due to the presence of non-asbestos particles. Likewise, concentrations reported as total asbestos are higher than fibers longer than 5  $\mu\text{m}$ , since fibers > 5  $\mu\text{m}$  typically only constitute a fraction of the total. Data from early studies that present results as  $\text{ng}/\text{m}^3$  or as f/cc estimated by calculation from such measurements (e.g., Selikoff et al. 1972, NRC 1984) have not been tabulated.

Because asbestos concentrations that are expressed in units of f/cc often have a number of leading zeros that can be difficult to read, all values in this report are expressed in scientific notation. For example, a concentration of 1E-03 is equal to 0.001 f/cc, and a concentration of 1E-04 is equal to 0.0001 f/cc.

### 3.2 Outdoor Air

Data that were located on the concentration of asbestos in outdoor air in the United States are tabulated in Table 1 and are presented graphically in Figure 1.

The most recent and most extensive report on the concentration of asbestos in outdoor air was provided by Lee and Van Orden (2007). As shown, based on TEM measurements, a mean value of 3E-05 f/cc > 5  $\mu\text{m}$  was observed for a data set of 1,678 outdoor samples collected in urban areas across the United States. Note that in this data set, the standard

deviation was  $3\text{E-}04$  f/cc, which reflects the high degree of variability that is often observed between individual samples.

Similar results have been reported by several others, including:

- Van Orden et al. (1995) observed a mean concentration of  $2\text{E-}04$  f/cc  $> 5$   $\mu\text{m}$  in a set of 25 measurements taken in outdoor air in the San Francisco area within five days of the 1989 Loma Prieta earthquake.
- USEPA (1988) (also reported in Chesson et al. 1991) reported a mean of  $4\text{E-}04$  f/cc  $> 5$   $\mu\text{m}$  in a set of 48 outdoor air samples collected in the vicinity of public buildings in five different geographic zones of the United States. As in the report by Lee and Van Orden (2007), the standard deviation was quite large ( $1\text{E-}03$  f/cc  $> 5$   $\mu\text{m}$ ), reflecting substantial between-sample variability.
- The Health Effects Institute-Asbestos Research (HEI-AR 1991) reviewed a wide range of published and unpublished reports on asbestos levels in outdoor air, and concluded the mean in rural areas was about  $1\text{E-}05$  f/cc  $> 5$   $\mu\text{m}$ , and was about ten-times higher ( $1\text{E-}04$  f/cc  $> 5$   $\mu\text{m}$ ) in urban areas.

### 3.3 Indoor Air

In the past, asbestos was used in a wide range of building materials (floor tiles, ceiling tiles, wall board, pipe insulation, roofing tiles, etc.). Consequently, indoor air may contain asbestos fibers due to releases from indoor ACM (especially when it is in poor condition) as well as to air exchange with outdoor air.

Data that were located on the concentration of asbestos in indoor air in buildings in the United States are tabulated in Table 2 and are presented graphically in Figure 2.

The most recent and most extensive report set on the concentration of asbestos in indoor air was provided by Lee and Van Orden (2007). Portions of the data included in this report were published earlier (Corn et al. 1991, Lee et al. 1992, Corn 1994). Data are presented from nearly 4,000 samples collected from over 700 different buildings, all analyzed by TEM. As shown in Table 2, indoor air concentrations of fibers  $> 5$   $\mu\text{m}$  generally average about  $5\text{E-}05$  to  $2\text{E-}04$  f/cc, with an overall average of about  $1\text{E-}04$  f/cc. As indicated by the relatively large standard deviation values, there is often substantial variation between samples, with “high end” (90<sup>th</sup> percentile) values often 3-5 times greater than the mean.

Generally similar values have been reported by other investigators, including:



- Tang et al. (2004) used TEM to measure the concentration of asbestos in 48 samples of indoor air from 25 residences and 9 building common areas in upper Manhattan as a way to characterize “background” levels for use in evaluation of exposures associated with the World Trade Center collapse. Asbestos was detected in only 2 of the 48 samples, each at a concentration of  $4\text{E-}04 \text{ f/cc} > 5 \text{ }\mu\text{m}$ . Treating the non-detects as zeros, the overall mean for the 48 samples was  $2\text{E-}05 \text{ f/cc} > 5 \text{ }\mu\text{m}$ .
- Van Orden et al. (1995) measured the concentration of asbestos in 188 indoor air samples from 44 different buildings in the San Francisco area several days after the Loma Prieta earthquake. The mean was  $4\text{E-}04 \text{ f/cc} > 5 \text{ }\mu\text{m}$ , which the authors concluded was not different from what had been reported previously by others (HEI-AR 1991, Lee et al. 1992).
- HEI-AR (1991) reviewed a wide range of published and unpublished reports on asbestos levels in indoor air. (This includes data from some of the early publications that are included in the reports by Lee and van Orden 2007 and USEPA 1988). Mean values ranged from  $8\text{E-}05$  to  $5\text{E-}04 \text{ f/cc} > 5 \text{ }\mu\text{m}$ .
- Crump (1990) (also reported in Price et al. 1992) reported a mean concentration of  $3\text{E-}05 \text{ f/cc} > 5 \text{ }\mu\text{m}$  for a set of 170 samples collected in 34 university buildings in Minnesota.
- In a preliminary draft report, Perkins (1987) (as cited in USEPA 1991) measured asbestos in indoor air in 5 homes with friable asbestos in the basement. Samples from the basements ranged widely, from ND to  $1\text{E-}01 \text{ f/cc} > 5 \text{ }\mu\text{m}$ . Samples from the living area were lower, ranging from ND to  $4\text{E-}03$  (mean =  $8\text{E-}04 \text{ f/cc} > 5 \text{ }\mu\text{m}$ ).
- The Consumer Products Safety Commission (CPSC 1988) (as cited in Price et al. 1992) collected 89 samples of indoor air from 49 different older residences in three U.S. cities (Cleveland, San Francisco, and Philadelphia). The mean was  $1\text{E-}04 \text{ f/cc} > 5 \text{ }\mu\text{m}$ , with a maximum value of  $2\text{E-}03 \text{ f/cc} > 5 \text{ }\mu\text{m}$ .

Factors that likely influence the level of asbestos in indoor air include the amount and condition of asbestos containing material (ACM) in the buildings. The U.S. Environmental Protection Agency (USEPA) sampled air inside 49 government-owned buildings for asbestos, stratified according to the amount and condition of ACM (USEPA 1988, Chesson et al. 1990). Three types of buildings were defined: 1) buildings without ACM (Category 1); 2) buildings with all or most ACM in good condition (Category 2); and 3) buildings with at least one area of significantly damaged ACM (Category 3). Air samples were collected at seven locations inside each building (two samples per location). All samples were analyzed by TEM, and all asbestos structures longer than  $0.5 \text{ }\mu\text{m}$ , including fibers, bundles and clusters, and matrices were included in total structure counts. Results are summarized below:

Category	Description	No. of Bldgs	No. of Samples	Concentration (total f/cc)	
				Mean	Stdev
1	No ACM	6	42	2E-03 (a)	2.0E-03
2	ACM in good condition	6	42	5.9E-04	5.2E-04
3	ACM in poor condition	37	255	7.3E-04	7.2E-04

Because these data are reported as total asbestos structures (rather than structures  $> 5 \mu\text{m}$  in length), the values are not comparable to the results from Lee and Van Orden (2007) and others in Table 2. However, the data do reflect a general trend for higher concentrations in indoor air as function of the amount and condition of ACM, and further document the high variability between samples, even within a category.

#### 4.0 Summary

Concentrations of asbestos in outdoor and indoor air are inherently variable due both to authentic variations over time and space, and also to variations in sampling and analytical methods.

Average concentrations in outdoor ambient air tend to range between about  $1\text{E-}05$  and  $4\text{E-}04 \text{ f/cc } > 5 \mu\text{m}$ , with an overall mean of about  $1\text{E-}05$  to  $3\text{E-}05 \text{ f/cc } > 5 \mu\text{m}$ . In general, concentrations in rural and remote areas tend to be lower than urban areas.

Average concentrations of asbestos in indoor air depend on the amount and condition of ACM, with values generally ranging from about  $1\text{E-}05$  to  $1\text{E-}03 \text{ f/cc } > 5 \mu\text{m}$ , with an overall mean of about  $1\text{E-}04$  to  $3\text{E-}04 \text{ f/cc } > 5 \mu\text{m}$ .

#### 5.0 References

ATSDR. 2001. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Asbestos. Atlanta: U.S. Department of Health and Human Services, Public Health Service.

Chesson EJ, Hatfield J, Schultz B, Dutrow E, and Blake J. 1990. Airborne asbestos in public buildings. *Environ Res* 51:100-107.

Corn M. 1994. Airborne concentrations of asbestos in non-occupational environments. *Ann Occup Hyg* 38:495-502.

Corn M, Crump K, Farrar RJ, Lee RJ, and McFee DR. 1991. Airborne concentrations of asbestos in 71 school buildings. *Reg. Toxicol. Pharmacol.* 13:99-114.

Crump KS. 1990. Asbestos, carcinogenicity and public policy. Letter to the Editor. *Science* 248:799.

CPSC. 1988. Phase one report of asbestos-in-home monitoring study. Memo to the Commission from Sandra Eberle, Program Manager, Chemical Hazard Program, Consumer Products Safety Commission, Washington DC. February 24. (As cited in Price et al. 2004).

Harper M. 2008. 10<sup>th</sup> Anniversary Review: Naturally occurring asbestos. *J Environ. Monit.* 10:1394-1408.

HEI-AR. 1991. Health Effects Institute. Asbestos in public and commercial buildings: A literature review and synthesis of current knowledge. Report of the asbestos literature review panel. Cambridge, MA: Health Effects Institute.

Keyes DL and Millette JR. 1991. Asbestos exposure from activities in buildings with asbestos-containing materials. *Ann. N.Y. Acad. Sci.* 643:509-10.

Kinney PL, Satterfield MH, and Shaikh RA. 1994. Airborne fiber levels during asbestos operations and maintenance work in a large office building. *Appl. Occup. Environ. Hyg.* 9:825-835.

Lee RJ and Van Orden DR. 2007. Airborne asbestos in buildings. *Reg. Toxicol. Pharmacol.* 50:218-225.

Lee RJ, Van Orden DR, Corn M, et al. 1992. Exposure to airborne asbestos in buildings. *Regul. Toxicol. Pharmacol.* 16:93-107.

Perkins RL. 1987. Asbestos in residential environments: Preliminary draft report. Research triangle Park, NC. Research Triangle Institute. Contract No. CR812281-01-0. (As cited in USEPA 1991).

Price B, Crump KS, Baird EC. 1992. Airborne asbestos levels in buildings: maintenance worker and occupant exposure. *J. Exposure Anal. Environ. Epidemiol.* 2:357-374.



Selikoff IJ, Nicholson WJ, and Langer AM. 1972. Asbestos air pollution. *Arch Environ Health* 25:1-13.

Tang KM, Nace CG Jr, Lynes CL, Maddaloni MA, LaPosta D, and Callahan KC. 2004. Characterization of background concentrations in upper Manhattan, New York apartments for select contaminants identified in World Trade Center dust. *Environ Sci Technol*. 38:6482-90.

USEPA. 1988. Assessing Asbestos in Public Buildings. United States Environmental Protection Agency, Office of Toxic Substances. EPA 560/5-88-002.

USEPA. 1991. Indoor-air assessment: Indoor concentrations of environmental carcinogens. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. EPA/600/8-90/042. NTIS No. PB91-193847.

Van Orden DR, Lee RJ, Bishop KM, Kahane D, and Morse R. 1995. Evaluation of ambient asbestos concentrations in buildings following the Loma Prieta earthquake. *Regul. Toxicol. Pharmacol*. 21:117-122.

WHO. 1998. Chrysotile asbestos: Environmental health criteria. World health Organization, Geneva: Switzerland.

TABLE 1. DATA SUMMARY FOR OUTDOOR AIR

Study	Year	Method	Location	Setting	#Samples	Concentration (s/cc > 5 $\mu$ m)	
						Mean	Stdev
Lee and Van Orden	2007	TEM	USA	Urban	1678	3E-05	3E-04
Van Orden et al.	1995	TEM	San Francisco	Urban	25	2E-04	
USEPA	1988	TEM	USA	Urban	48	4E-04	1E-03
HEI-RI	1991	TEM	USA	Rural		1E-05	
				Urban		1E-04	

FIGURE 1. DATA SUMMARY FOR OUTDOOR AIR

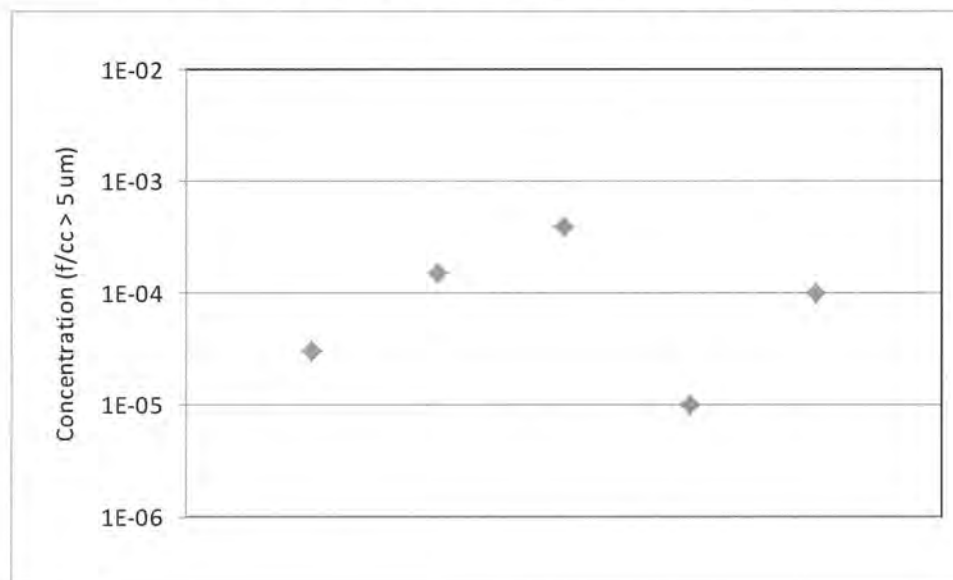


TABLE 2. DATA SUMMARY FOR INDOOR AIR

Study	Year	Location	Method	Building type	# Bldgs	# Samples	Concentration (f/cc > 5 $\mu$ m)			
							Mean	Range	Stdev	High end (a)
Lee and Van Orden	2007	USA	TEM	All	752	3979	1E-04		4E-04	5E-04
				Public	114	590	7E-05		2E-04	4E-04
				Commercial	120	746	1E-04		4E-04	3E-04
				Residential	5	39	5E-05		1E-04	
				School	317	1615	2E-04		4E-04	6E-04
Tang et al.	2004	New York City	TEM	University	196	989	9E-05		4E-04	
				Residential	25	48	2E-05	ND - 4E-04		
Van Orden et al.	1995	San Francisco (following earthquake)	TEM	Common areas	9	14	3E-05	ND - 4E-04		
				All	44	188	4E-04			
				School	24	81	2E-04			
				University	3	9	ND			
				Commercial	13	68	8E-04			
HEHRI	1991	USA	TEM	Public	3	28	4E-04			
				Residential	1	2	2E-03			
				All	198	1377	3E-04			1E-03
				School			5E-04			
Crump Price et al.	1990 1992	Minnesota	TEM	Residence			4E-04			
				Public/commercial			8E-05			
Perkins USEPA	1987 1991	USA	TEM	University	34	170	3E-05			6E-04
				Residential (basement) (b)	5	5	2E-02	ND 1E-01		
CPSC Price et al	1988 1992	3 US Cities	TEM	Residential (living area)	5	5	8E-04	ND 4E-03		
				Residential	49	89	1E-04			2E-03

- (a) 90th, 95th, or max  
(b) Damaged ACM  
(c) Excludes one outlier

FIGURE 2. DATA SUMMARY FOR INDOOR AIR

